Conventional Plays

Upper Cretaceous-Lower Tertiary Play

(USGS 4101)

General Characteristics

This hypothetical, continuous-type "tight-gas" play is largely restricted to the marginal marine, partly deltaic Trinidad Sandstone. Although, stratigraphic traps could occur in the Vermejo and Raton Formations (Fig. P-37). Dolly and Meissner (1977) estimated the uppermost Cretaceous/lowermost Tertiary section may have generated approximately 23 TCFG, of which approximately 6 TCFG may be recoverable. Additionally, as much as 750 BCF of recoverable gas reserves exists in basin-centered gas in the northern portion of the Raton Basin.

Reservoirs: The Cretaceous Trinidad Sandstone, characterized as marginal marine and partly deltaic, is the potential reservoir rock. General thickness probably varies between 100 and 250 feet. Reservoir sandstones may be as much as 50 feet thick and reservoir porosity is probably 10-14 percent, but porosity usually varies between 2 and 18 percent. Other potential clastic reservoirs include the Cretaceous Vermejo and Cretaceous/Paleocene Raton Formations.

Source rocks, timing, and migration: Pierre Shale and coal/carbonaceous beds are potential sources in the Vermejo, Raton, and Poison Canyon Formations. Generation and migration probably began no earlier than Eocene.

Traps: Trinidad Sandstones, in a basin-center environment, may lack a conventional seal. Depth to production is rather shallow, ranging between approximately 4,000 and 6,000 feet.

Exploration status and resource potential: The play is poorly explored. It is possible that a few new discoveries will exceed 6 BCFG. A number of small gas fields possibly could be found.

Jurassic-Lower Cretaceous Play

(USGS 4102)

General Characteristics

This is a high-risk play, and potential reservoirs are restricted to Jurassic Morrison and Cretaceous Dakota Sandstones deposited as highly lenticular marine bars and fluvial channels (Fig. P-38). Sandstones may be fine to coarse grained, 10-40 feet thick and log-derived porosity may reach 15-25 percent. Field pressure, determined from the now-abandoned Wagon Mound Field (Mora County, New Mexico) is low.

Reservoirs: Jurassic Morrison and Cretaceous Dakota Sandstones, deposited as highly lenticular marine bars and fluvial channels, are the potential reservoirs. Sandstones are fine to coarse grained, 10-40 feet thick. Porosity, determined from logs (Figs. 39 and 40), varies between 15 and 25 percent and permeability appears high. Field pressure is low (5.5 psi). Most of the gas has been found in the upper Dakota Sands.

Source rocks, timing, and migration: Shale and coal are possible sources within the Purgatoire-Dakota sequence, and overlying shales include potential source beds for oil and gas. Generation probably began in early Tertiary (Eocene-time) when overlying strata were at least 10,000 feet thick. Migration probably began in the Eocene.

Traps: Gas was structurally trapped in the Dakota Sands in a low-relief, northeast-trending Laramide Anticline. Some gas was trapped in lenticular, fluvial Jurassic Morrison Sandstones. Interbedded shales probably act as traps. Depth to known occurrences is 500-5,000 feet.

Exploration status: The play is poorly explored. It is unlikely that new discoveries will exceed 6 BCFG or 1 MMBO. A number of small gas fields could probably be found.

Resource potential: This is a high risk play; undiscovered resources are estimated to be of small size.

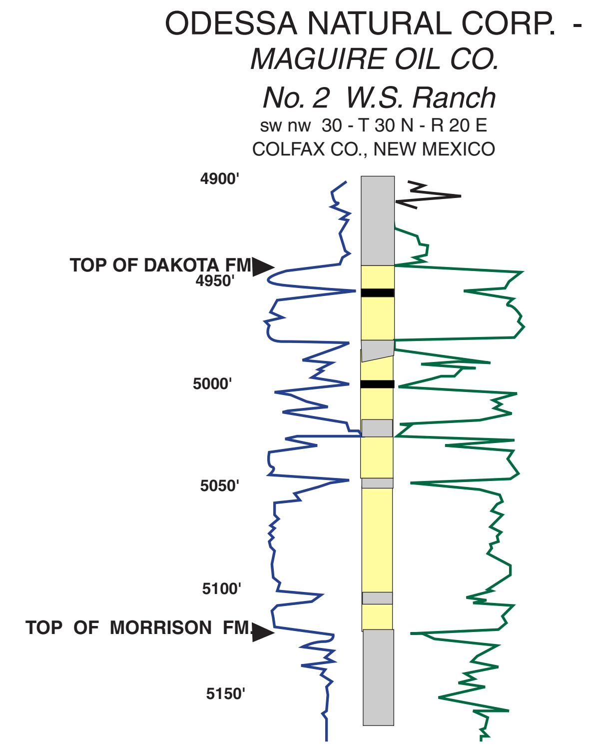


Figure P-39. Typical gamma-ray log of Dakota Formation in south-central Raton Basin (modified after Gilbert and Asquith, 1976).

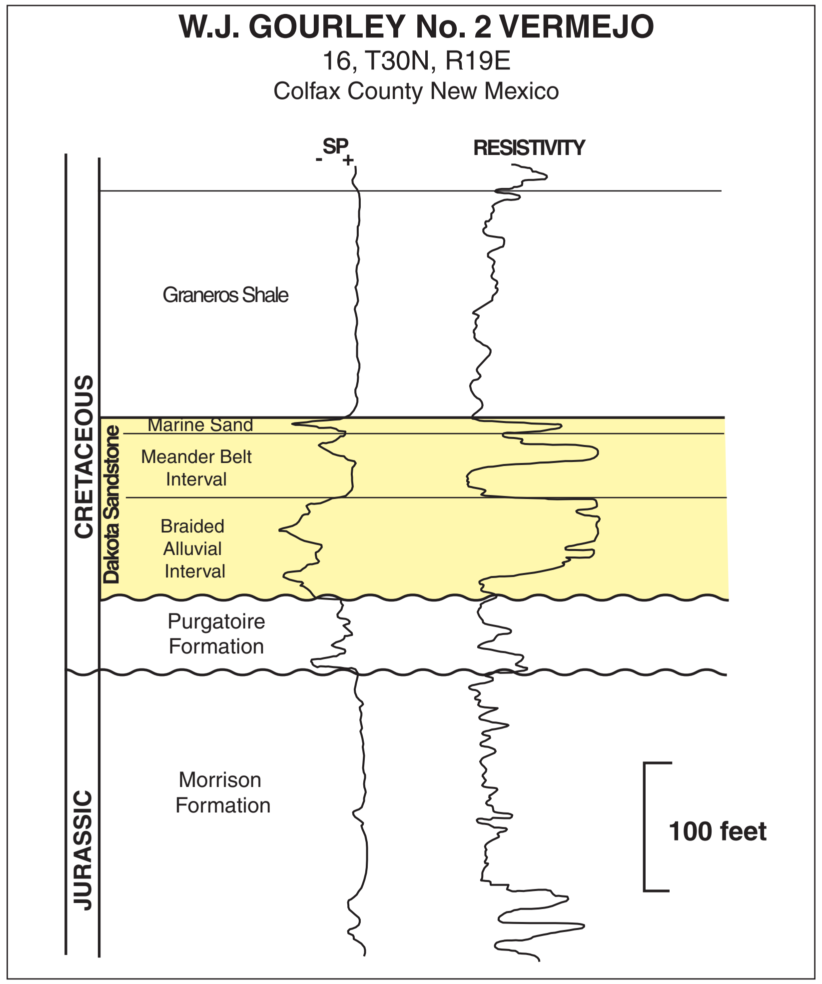


Figure P-40. Typical electric log characteristics of the Dakota Sandstone in the Raton Basin, Colfax County, New Mexico (modified after Gilbert and Asquith, 1976).

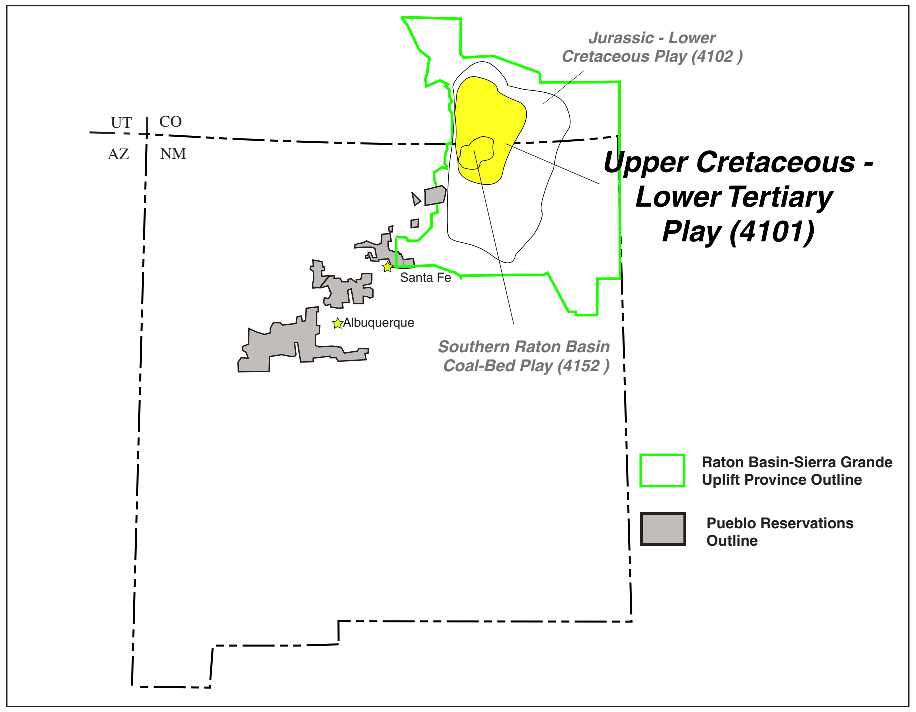


Figure P-37. Upper Cretaceous-Lower Tertiary Play (4101) with respect to the Pueblo Indian Reservations (modified after Gautier et al., 1996).

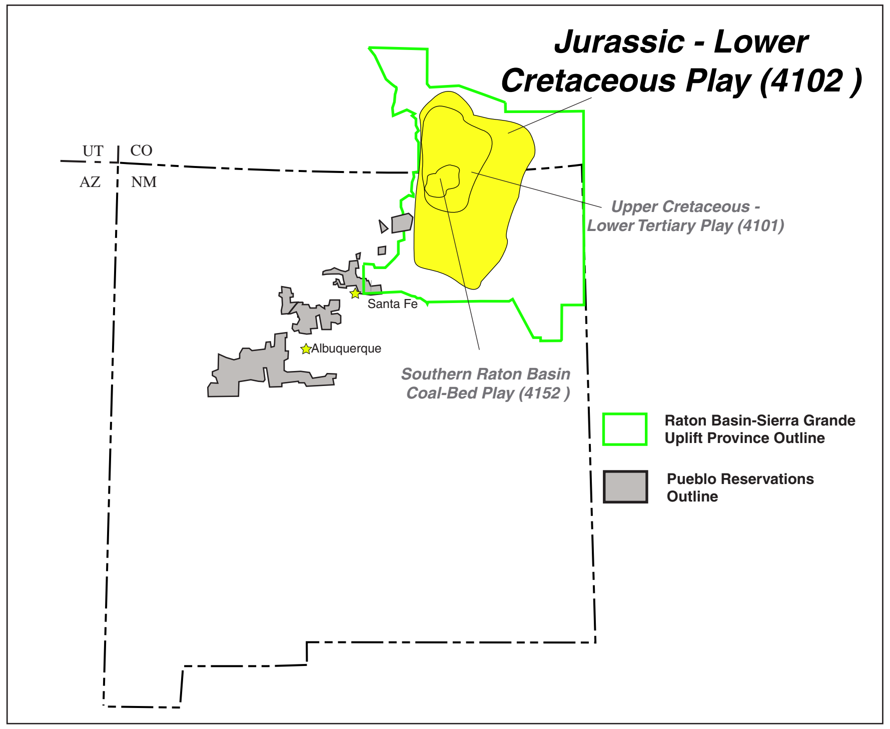


Figure P-38. Jurassic-Lower Cretaceous Play (4102) with respect to the Pueblo Indian Reservations (modified after Gautier et al., 1996).

UNCONVENTIONAL PLAYS

Coal-Bed Gas Plays

Three coal-bed gas plays are identified in the Raton Basin Province. The Southern Raton Basin Play (4152) is relevant to the Pueblo Indian Reservations (Fig. P-41). Tyler et al., 1991; Stevens et al., 1992; and Close and Dutcher, 1993, have described the geologic controls and potential of coal-bed gas in the Raton Basin, southeastern Colorado and northeastern New Mexico.

In the Raton Basin, coal beds with potential for coal-bed g as are contained within the Upper Cretaceous Vermejo and Upper Cretaceous-Paleocene Raton Formations (Fig. P-42). The Vermejo Formation is as much as 350 feet thick and individual coal seams are as much as 14 feet thick. The cumulative coal thickness for the formation ranges from 5 to 35 feet. The overlying Raton Formation is as much as 1,600 feet thick and has a net coal thickness in the range of 10 to 120 feet. Although the Raton Formation contains more coal, individual coal seams are thinner, more discontinuous, and distributed over 1,200 feet of section. The nature of the coal seams in the two formations is controlled by depositional environment; the Vermejo was deposited in a lagoonal environment; whereas, the Raton was deposited in a fluvial setting. Although coal beds are as much as 4,100 feet deep in the northern part of the basin along the LaVeta Syncline, they are generally less than 1,200 feet over a large part of the basin.

The rank of coals in the Vermejo Formation ranges from high-volatile C bituminous along the margins of the basin to low-volatile bituminous in the central part of the basin. The rank generally coincides with present-day depth of burial and structural configuration, and probably resulted from maximum depth of burial that occurred in early Tertiary time. However, the highest ranks (low-volatile bituminous) occur along the eastward-flowing Purgatoire River where the present-day depths of burial are less than about 1,200 feet. These high ranks are interpreted to be the result of high heat flow from the crust, upper mantle, and (or) deep igneous intrusions which was transferred laterally by groundwater flow in middle Tertiary time. During this time, Vermejo and Raton coal beds commonly served as planes of weakness for igneous intrusions. However, the thermal maturity of the coal beds is only locally affected (one-dike width) by the intrusions.

Coal-bed g ases from production tests in the Raton Basin are composed mostly of methane with minor amounts of ethane, carbon dioxide, and nitrogen (each less than 1 percent). Isotopic analyses indicate that the gases are predominantly of thermogenic origin and were probably generated during time of maximum burial and (or) heat flow. Some mixing of relatively recent biogenic gas may occur in areas of groundwater flow.

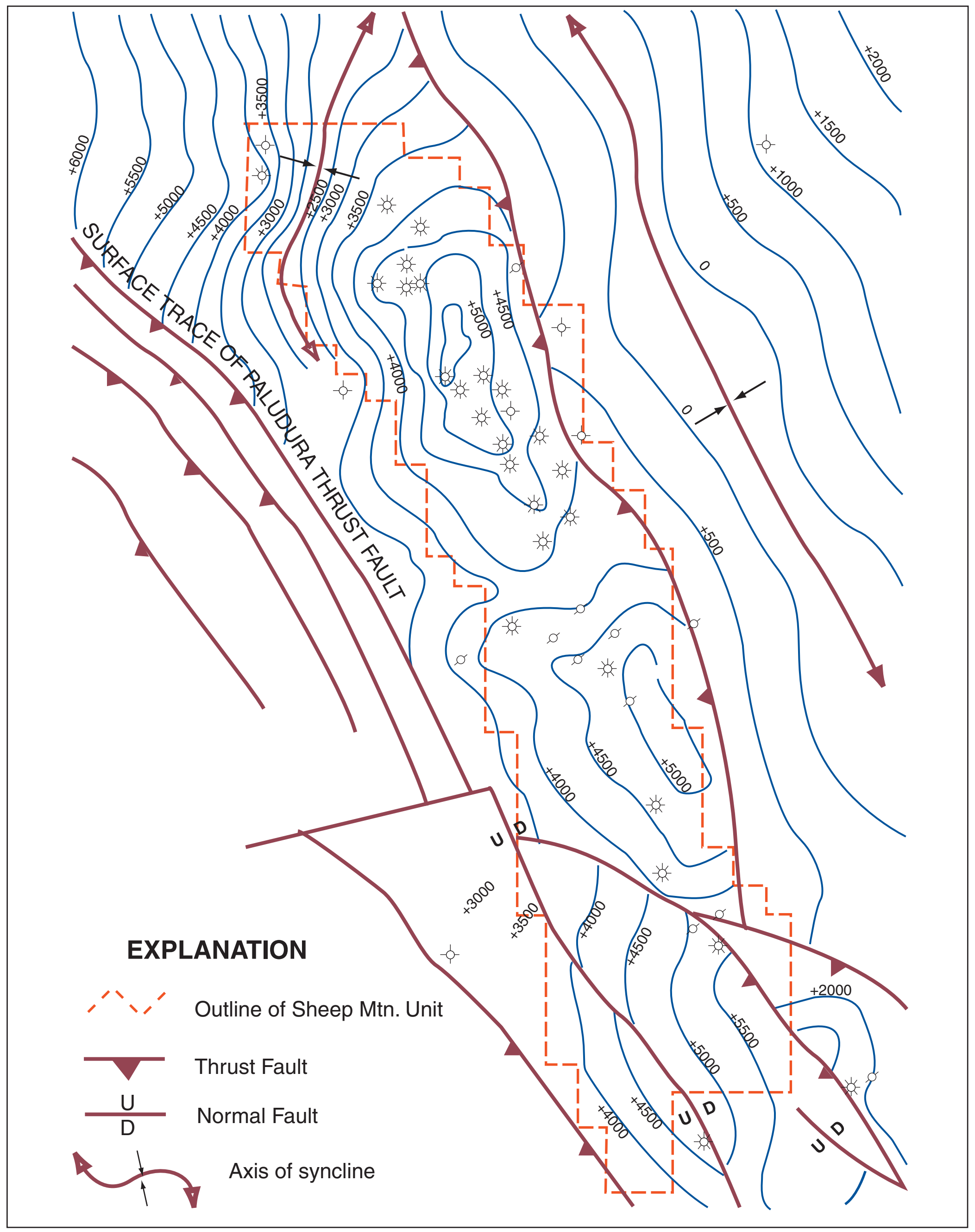
The Raton Basin is a strongly asymmetric basin with a gently dipping eastern flank and a steeply dipping western flank that is thrust-faulted (Fig. P-9). Several major folds are located along the western margin of the basin. Minor normal faulting occurs within the basin with displacements generally less than 50 feet. The primary fracture permeability system in both the coals and adjoining rocks is oriented east-west.

Groundw ater recharges the topographically high Vermejo-Raton Aquifer along the western margin of the basin and flows eastward to discharge at the topographically lower eastern outcrops along major seeps and drainage areas (Geldon, 1989; Stevens et al., 1992). The primary fracture (face cleat) trend in the Raton Basin coals is perpendicular to the local trend of the Sangre de Cristo thrust front and thus enhances groundwater flow and the potential for artesian overpressuring (Tyler et al., 1991).

Gas contents of coal beds in the basin are highly v ariable and range from 4 to 810 Scf/t. These contents seem to correlate more closely with depth below the hydrologic potentiometric surface than with depth below the ground surface. On the basis of coal thickness, coal density, drillable area, and gas content, in-place coal-bed gas resources of the Raton Basin are estimated to be as much as 12 TCF (Fig. P-42).

Some coal is produced by both under ground and surface methods in the Colorado and New Mexico parts of the basin. Mine-related emissions are minor. An explosion in an underground mine near Trinidad, Colorado, indicates that the coal beds are gassy.

Since the late 1970's, more than 110 exploration wells have been drilled for coal-bed gas in the Raton Basin, both in Colorado and New Mexico. Production tests have been variable, but gas rates of more than 300 MCF/D have been reported. At present, all wells are shut-in because of the absence of gas pipelines in the basin. However, a pipeline is under construction and a pilot nitrogren injection project for coalbed gas wells has been approved (Rice and Finn, 1995).



<- Figure P-41. Structure map of the Sheep Mountain Field showing the outline of the Sheep Mountain unit. Datum is the top of the Dakota Sandstone Formation (modified after Roth, 1983).

Analog Field Within Raton Basin
(near Pueblo Indian Reservations)

Sheep Mountain Field
(Figure P-41)

Location of Discovery Well:	No .1 Faris, nw se 15, T25S, R70W
Producing Formation:	Cretaceous Dakota Ss; Jurassic Entrada Ss
Type of Trap:	Stratigraphic (shale)
Initial Production:	4900 MCFD
Cumulative Production:	NR
Gas Characteristics:	NR
Type of Drive:	Gas pressure
Average Net Pay:	350 feet, 110 feet
Porosity:	NR
Permeability:	NR

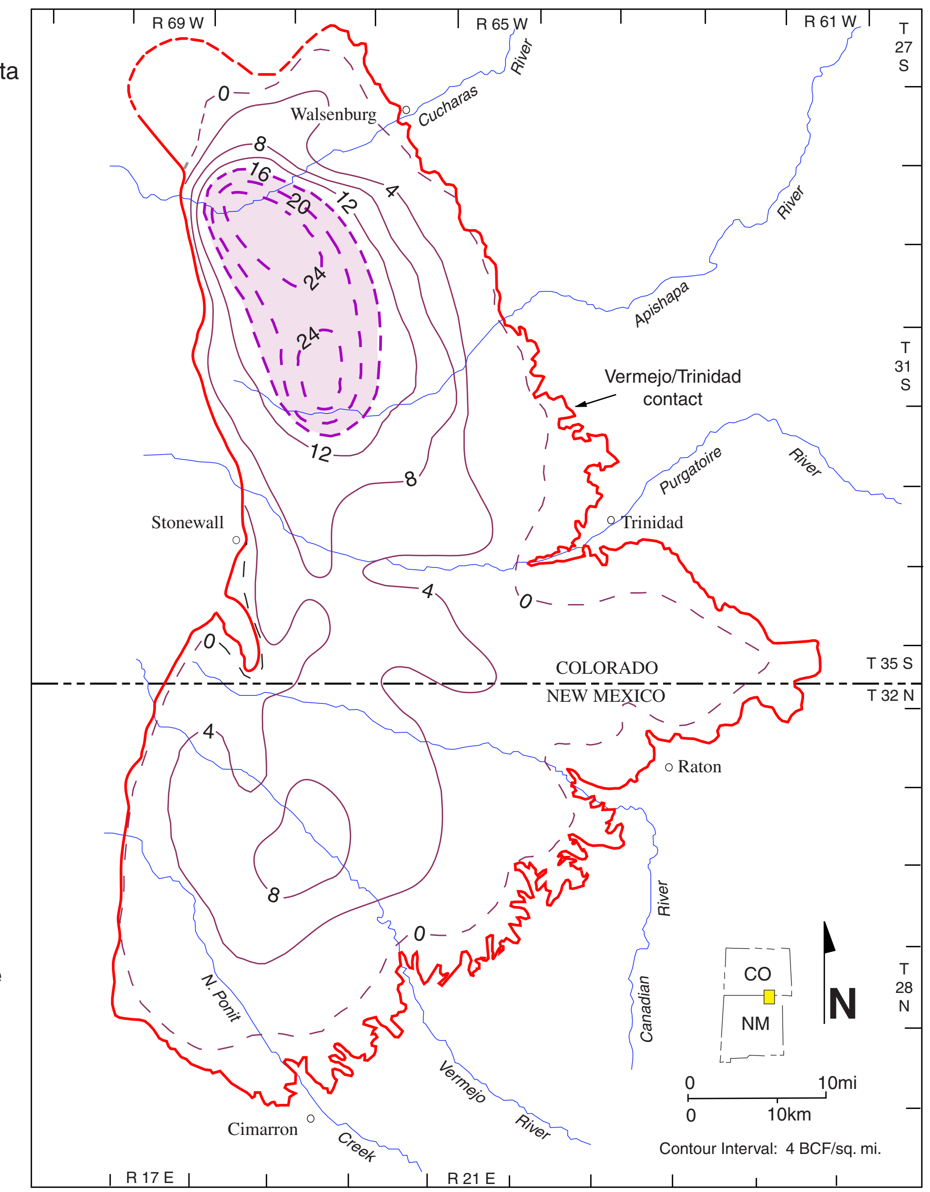


Figure P-42. -> Raton Basin coal-bed methane in place, contoured in 4 BCF/mi intervals; data inside the 16 BCF/mi contour have a high degree of uncertainty (modified after Stevens et al., 1992).

Southern Raton Basin Play

(USGS 4152)

General Characteristics

The target area for coal-bed gas is where coal beds of the Vermejo and Raton Formations are greater than 500 feet deep. The thicker, more continuous seams of the Vermejo Formation are probably better targets for coal-bed gas production. The Southern Raton Basin Play target area (Fig. P 43) is based on depth, coal rank, and concentration of gas in place. Exploration wells have been drilled for coal-bed gas in the play, but production has not been established (as of 1996). The reserve potential of coal-bed gas from all three plays is considered very good, but production will depend on infrastructure development, particularly pipeline construction.

In the Southern Raton Basin Play (4152), coal ranks are as much as medium-volatile bituminous, but depths of burial are less than 1,400 feet. Because of these relatively shallow depths, concentra tions of gas in-place are about 8 BCF/square mile or less. The re serve potential of this play is also regarded as good (Rice and Finn, 1995).

South-Central New Mexico Province

This frontier petroleum province covers about 39,900 square miles, primarily in the easternmost part of the Basin and Range Physio graphic Province; it has no production (Fig. P-44). For a more com plete description of this province, see Butler, 1988; and Grant and Foster, 1989.

Small, northeast-trending rift basins are the predominant ph ys iographic feature of the South-Central New Mexico Province. As much as 10,000 feet of alluvium and volcanic rocks fill these exten sional basins, obscuring a moderately thick section of Paleozoic stra ta.

This pro vince has a complex geologic history, having been de formed by three major periods of tectonism during Phanerozoic time: (1) Late Paleozoic formation of the Ancestral Rocky Mountains, (2) Laramide compression, and (3) Cenozoic relaxation and extension and volcanism. South-Central New Mexico was near the terminus of the northeast-trending transcontinental basement arch during the Late Proterozoic and Paleozoic. Within this time span, sediments were deposited in platform, shallow shelf, basinal, and alluvial plain envi ronments. Epeiric seas generally transgressed from the south, and thus a greater thickness of strata was deposited during this time in the southern part of the province. During the mid-Paleozoic, general quiescence of the craton in the equatorial paleo-latitudes resulted in widespread deposition of fossiliferous carbonates accompanied by basin-margin organic buildups. Convergence of the North and South American tectonic plates in the late Paleozoic resulted in intraplate defor mation.

T riassic and Jurassic strata are not well represented in the province, which depositio nally represents an erosional surface shifting from highlands to interior lowlands and coastal plains. Nascent opening of the Gulf of Mexico (Chihuahua Trough) deposited as much as 750 feet of marine Jurassic sediments in the south ernmost Mesilla Basin. Continued opening near the New Mexico-Mexico border resulted in an east-west Early Cretaceous rift, extending into southeastern Arizona. A thick Late Creta ceous section of marine sandstones and shales and continental fluvial clastics and paludal coals was deposited as seas transgressed and re gressed from the north-northeast and from the south-southwest; about 3,000 feet of this sec tion is preserved. Laramide compression from the southwest re juvenated older fault-bounded structures and other paleo-zones of weakness (for example thrust faults) and created basement-cored up lifts. Plutons, with attendant rich mineralization, intruded the prov ince. Early Tertiary uplift provided cyclic alluvial-fluvial fan grav els and deltaic clastics to continental interior-drained basins and small lakes.

T wo hypothetical conventional plays were assessed in this province. They are Orogrande Basin Play (2602) and Mesilla-Mimbres Basins Play (2603), neither of which occur in or near the Pueblo Indian Reservations. However, limited exploration has occurred within the Acoma Basin Play, which underlies a segment of the Pueblo Reserva tion. A brief description of the production within the Acoma Basin is presented in the following section.

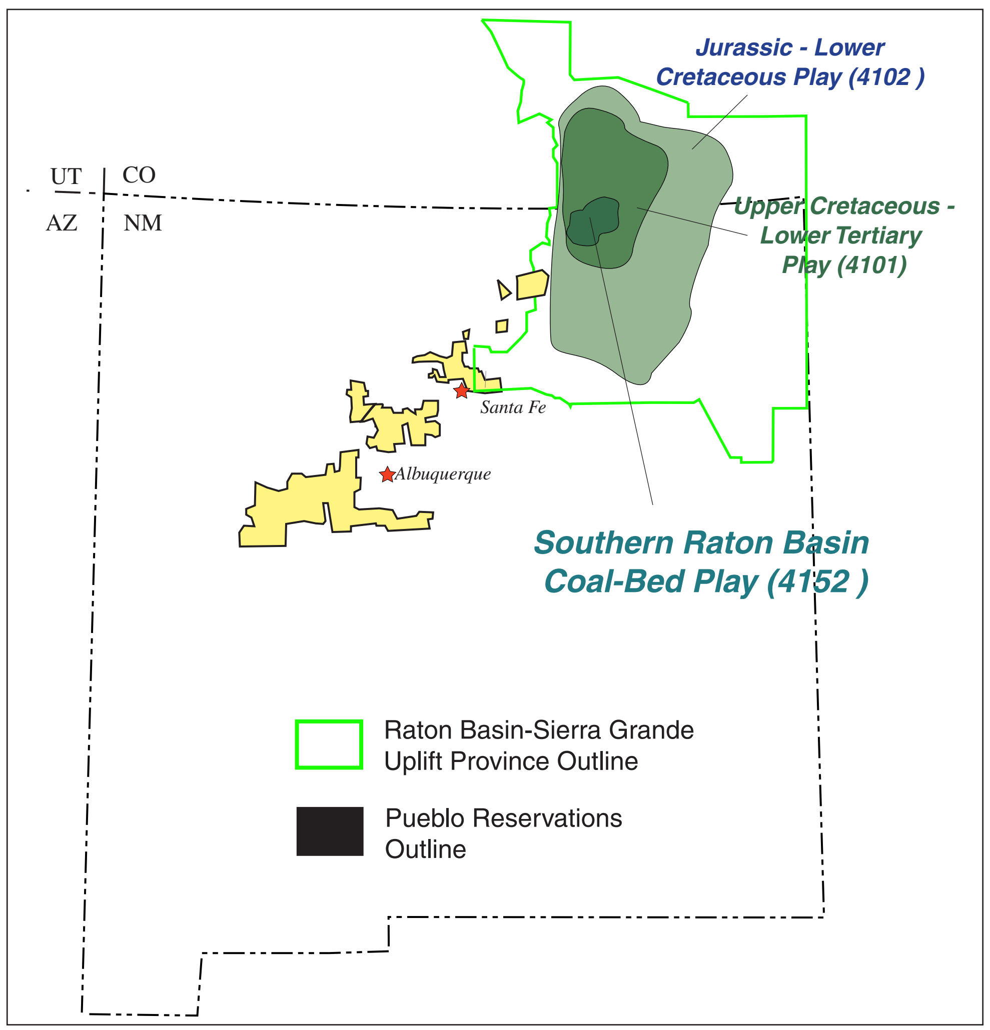


Figure P-43. Southern Raton Basin Coal-Bed Play (4152), with respect to the Pueblo Indian Reservations (modified after Gautier et al., 1996).

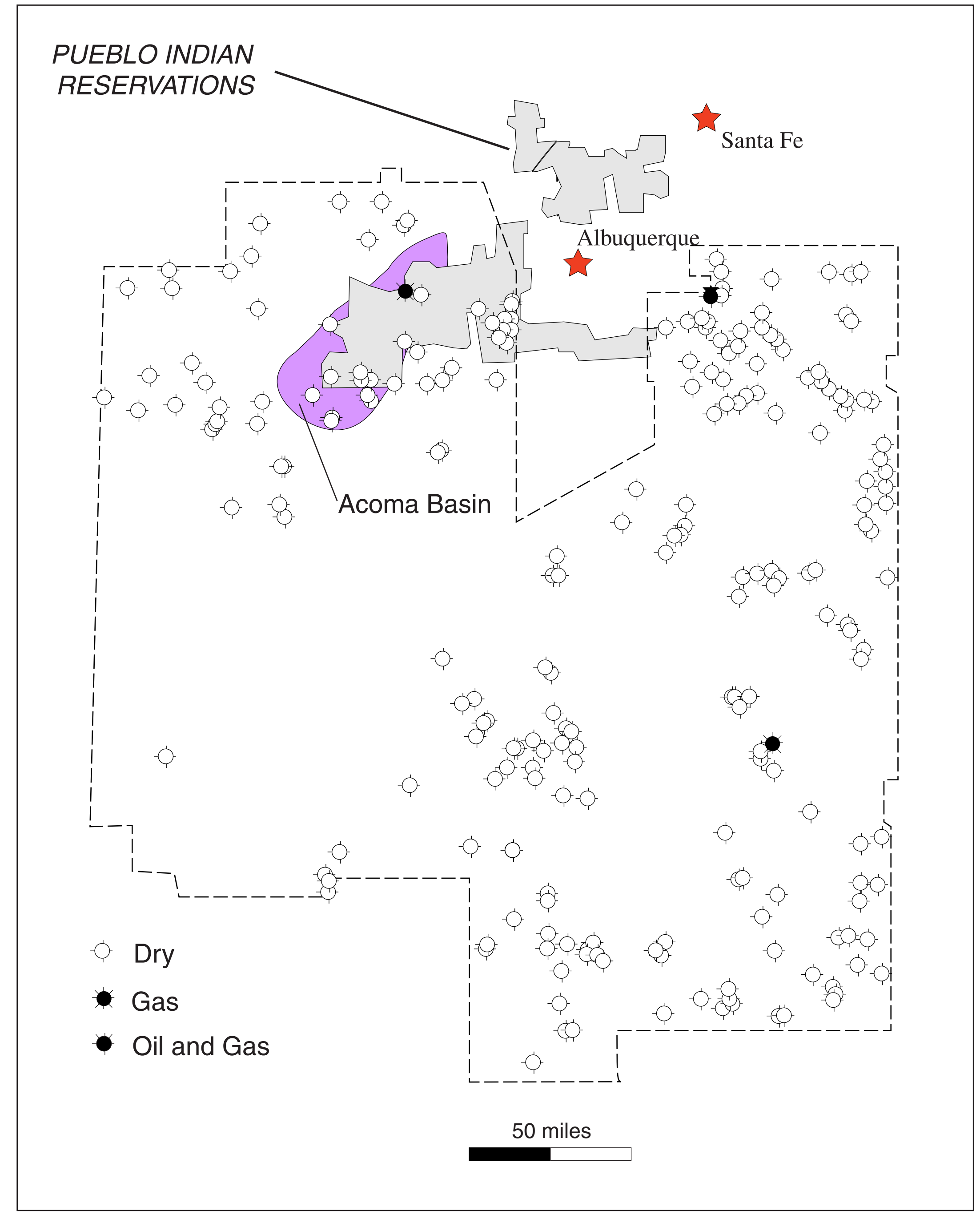


Figure P-44. Outline of South-Central New Mexico Geologic Province with exploration wells from 1900-1993 illustrated. The Acoma Basin is highlighted (modified after Gautier et al., 1996).

Acoma Basin Play

The Acoma Basin has seen limited exploration since the 1920's (Fig. P-45). The boundary between the Acoma Basin and the San Juan Basin to the northwest and the eastern Baca Basin is transitional.

Three significant exploratory wells have been drilled in the Acoma Basin since 1981. The Topaz Southwest Number 1 State tested Cretaceous sandstones and shales and Jurassic sandstones with no reported shows. The Austra-Tex Numbers 1 through 7 Rio Puerco Federal, were drilled to test the Pennsylvanian section (Fig. P-46).

Primary reservoir targets in the Acoma Basin are Permian limestones and sandstones of the San Andres and Yeso Formations and Pennsylvanian sandstone and limestones (Fig. P-47). The Cretaceous Mesaverde and Dakota Sandstones are secondary reservoir targets that have been eroded from the eastern part of the basin and are present only at shallow depths (less than 1500 feet {Broadhead, 1989}) in the western part of the basin (Fig. P-48). Pennsylvanian and Cretaceous marine shales are potential source rocks, but the Cretaceous section may be thermally immature (Broadhead, 1989).

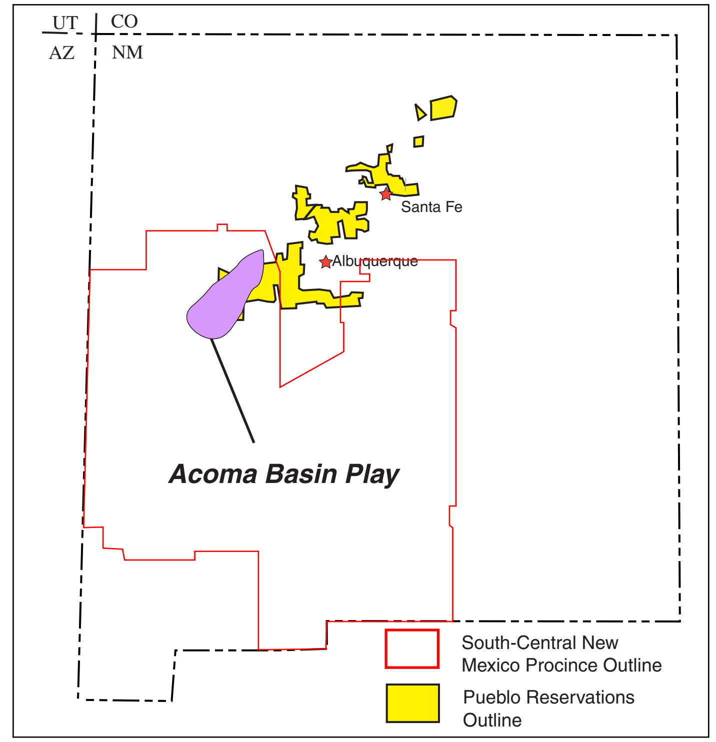


Figure P-45. Outline of the South-Central New Mexico Province with the Acoma Basin Play Highlighted (modified after Gautier et al., 1996).

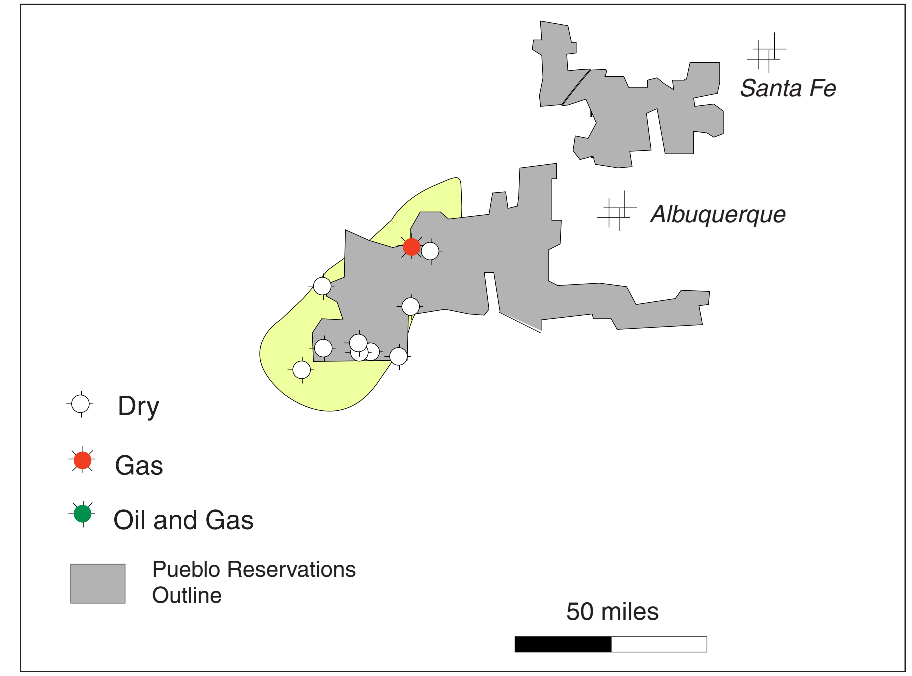
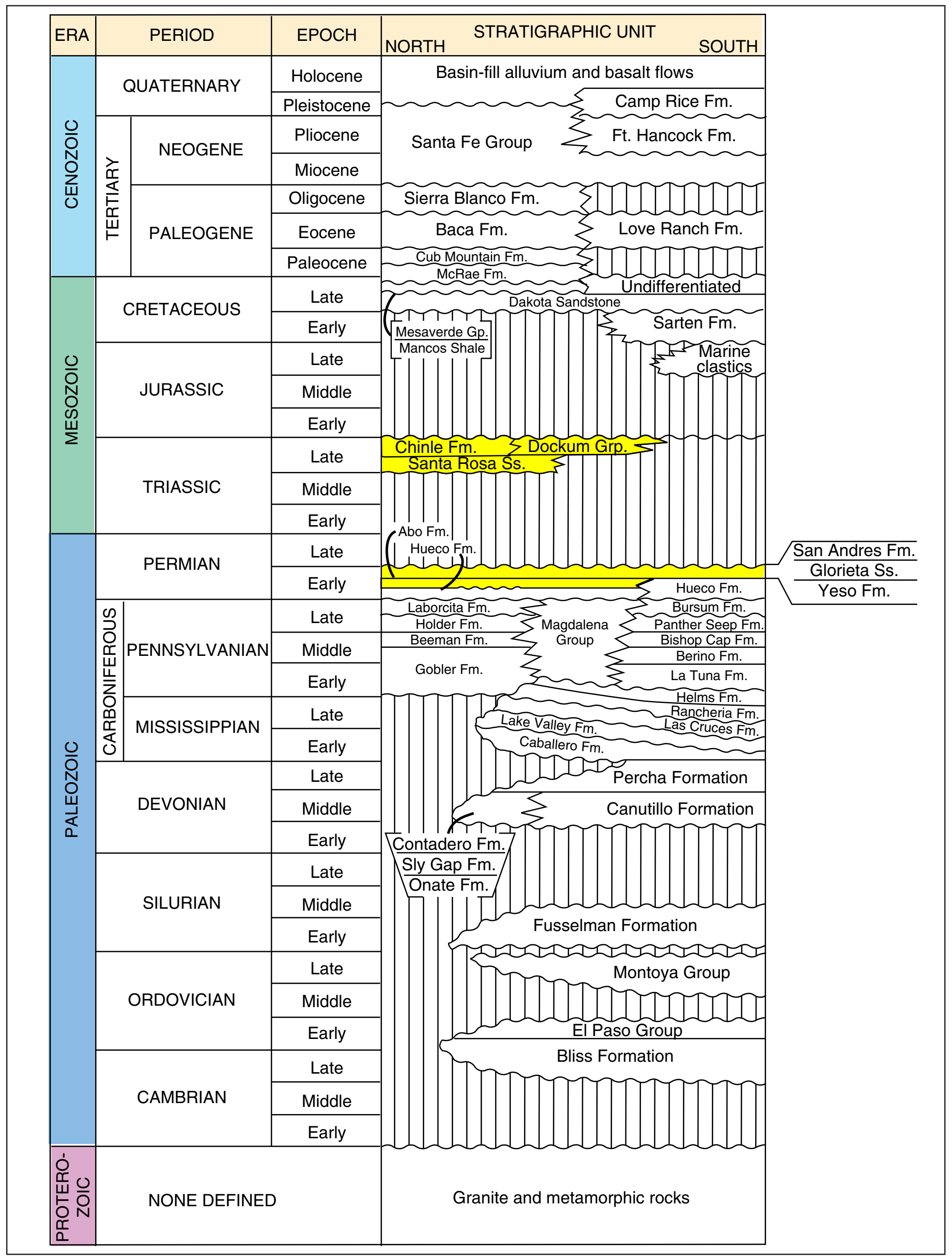


Figure P-48. Location of exploration wells in Acoma Basin (modified after Gautier et al., 1996.)



<-Figure P-46. Stratigraphic section depicting bedding relationships within the South-Central New Mexico Geologic Province (modified after Gautier et al., 1996).

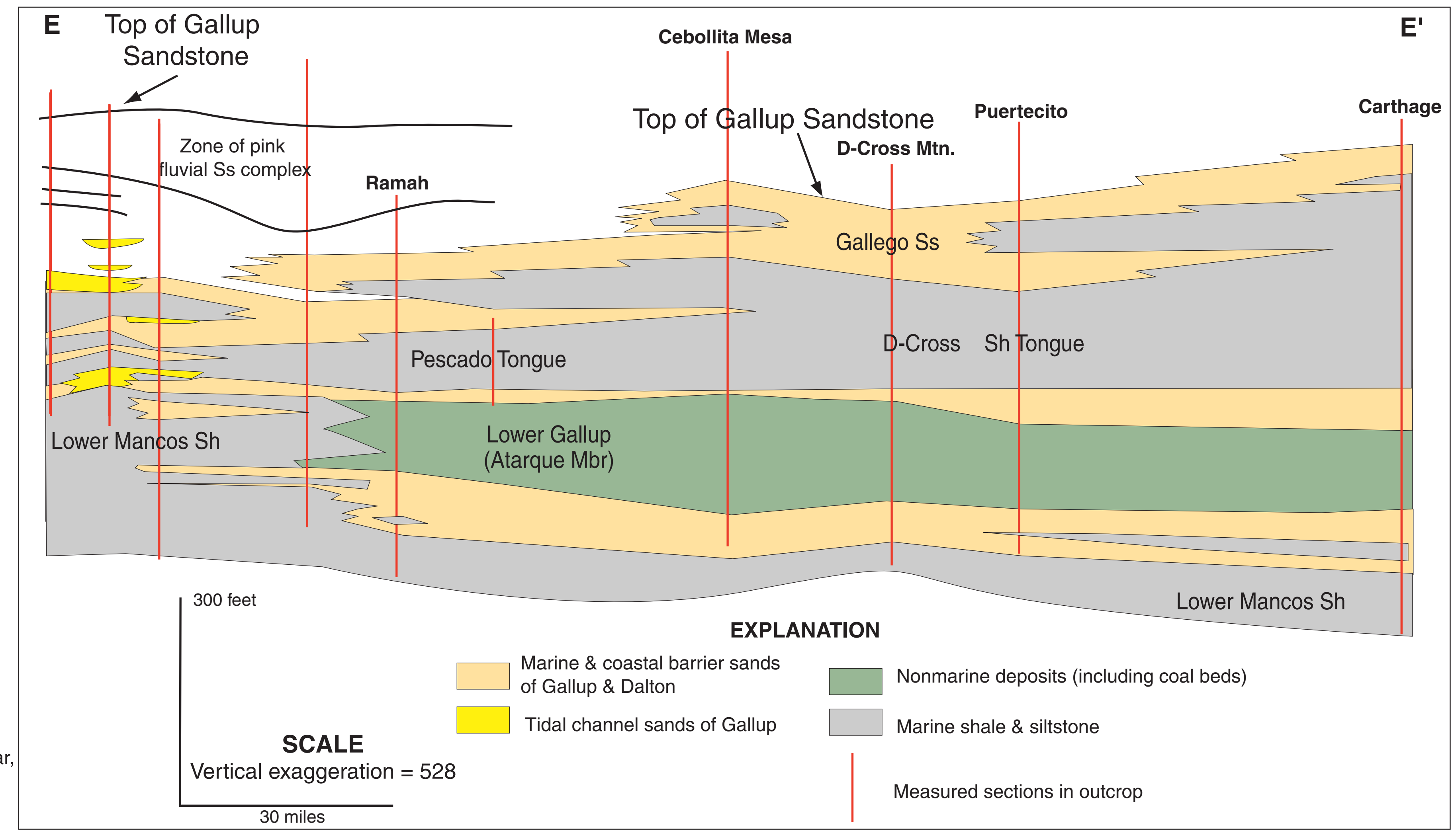


Figure P-47.-> Stratigraphic cross-section E-E' of the Acoma Basin (Fig. P-7; cross-section 5) (modified after Molenaar, 1974).

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